Analysis of Simultaneous Acoustic/Microwave Data

Peter H. Dahl
William J. Plant
Applied Physics Laboratory
University of Washington
1013 NE 40th St
Seattle, WA 98105-6698
Dahl: phone: 206-543-2667   email: dahl@apl.washington.edu
Plant: phone: 206-543-7836   email: plant@apl.washington.edu
fax: 206-543-6785

LONG-TERM GOALS

The long-range objective of this project is to understand both acoustic and microwave scattering from rough water surfaces sufficiently well to be able to implement them in operational models and, if possible, to remotely sense microscale breaking on the sea surface.

SCIENTIFIC OBJECTIVES

The scientific objectives of this research are to apply acoustic and microwave techniques of surface backscatter to investigate the bound and breaking waves that have been shown to exist on rough water surfaces, both in the laboratory and on the ocean.

The work is particularly aimed at determining the angular dependence of bound waves and their relationship to microscale breaking waves.

APPROACH

Our approach is to observe both acoustic and microwave backscattering from wind-roughened water surfaces in wind wave tanks, and to model the surface in a manner that will explain both types of scattering. The acoustic and microwave systems used are fully coherent so that Doppler spectra as well as backscattering cross sections can be obtained. Our wave tank arrangements are designed so that the acoustic and microwave systems both observe the surface at the same incidence angle. We use acoustic and microwave systems whose transmitted wavelengths are within 10% of each other.

WORK COMPLETED

In 1998, we carried out measurements in the UW wavetank at 0.8 and 2 cm looking both up and downwind. The results of the measurements at 0.8 cm clearly showed that the backscatter could be explained as Bragg scattering from parasitic capillary waves riding on the front faces of longer waves (Plant et al., 1999a). Scattering from 2 cm waves did not appear to be due to parasitic capillary waves, however.

Report Documentation Page

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Analysis of Simultaneous Acoustic/Microwave Data**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Physics Laboratory,University of Washington,,1013 NE 40th St,,Seattle,,WA, 98105**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT **The long-range objective of this project is to understand both acoustic and microwave scattering from rough water surfaces sufficiently well to be able to implement them in operational models and, if possible, to remotely sense microscale breaking on the sea surface.**

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

In order to further investigate surface scattering at these two wavelengths, we carried out a series of measurements in the large wind wave tank in Marseilles, France in the summer and fall of 2000. Microwave and acoustic data were collected with both 8mm and 2cm radiation at a variety of incidence angles, azimuth angles, and wind speeds. These data have allowed us to investigate the azimuth angle dependence of backscatter from bound and breaking waves (reported last year) and to compare the results at the long fetch (for a wavetank) in the Marseilles tank with the shorter fetch data collected at UW. The past year has been spent continuing these comparisons.

RESULTS

The results of our investigations show that classical parasitic capillary waves are not the only small-scale waves produced by gravity waves. We base this conclusion on the cross sections, phase speeds, and bandwidths of the observed scatterers in our experiments. For classical parasitic capillary waves, the phase speeds must be the same as the intrinsic phase speed of the capillary wave (Fedorov and Melville, 1998) and, within experimental error, this was the case for 8 mm backscatter observed in the short-fetch UW tank (Plant et al., 1999a). In the following, though, we show that, at the longer fetches of the Marseilles tank, bound, tilted scatterers other than parasitic capillaries also contribute to 8 mm backscatter and that at all wind speeds and fetches that we have examined, these other bound scatterers affect the backscatter at 2 cm.

In Figure 1, we demonstrate the characteristics of backscatter of 8 mm acoustic and electromagnetic radiation from the same rough surface at the same incidence angles. The figure shows cross sections, Doppler offsets, and Doppler bandwidths as a function of wind friction velocity at various fetches. Data at the 5 m fetch, the red symbols, were obtained in the UW wind wave tank in 1998 while data at the 6.3 (green) and 25.5 (blue) m fetches were measured in the Marseilles wind wave tank in 2000. As we pointed out last year, the difference between cross sections at low wind speeds at 5 and 25.5 m fetch is striking. Taken together with the behavior of the offsets and bandwidths, which are identical for HH and VV microwave backscatter and for acoustic backscatter, we interpret these data to indicate that parasitic capillaries alone are responsible for 8 mm backscatter at low wind speeds. At higher wind speeds or at the long fetch, all quantities behave very differently, indicating that other bound waves are involved in the scattering process. The presence of bound waves is clear from the fact that acoustic cross sections are much lower than microwave ones at all but the highest wind speeds and longest fetch when both sensors look upwind while HH microwave and acoustic cross sections are close together when they look opposite directions. Note that the general increases in Doppler offset and bandwidth with fetch shows that the long waves that produce the bound waves become longer with fetch, as one would expect for the dominant waves in the tank. The fact that Doppler offsets for acoustic and VV microwave return come together for long fetches and high wind speeds in the case where sonar and radar look upwind shows that neither is responding strongly to the rapidly moving bound waves, as expected.
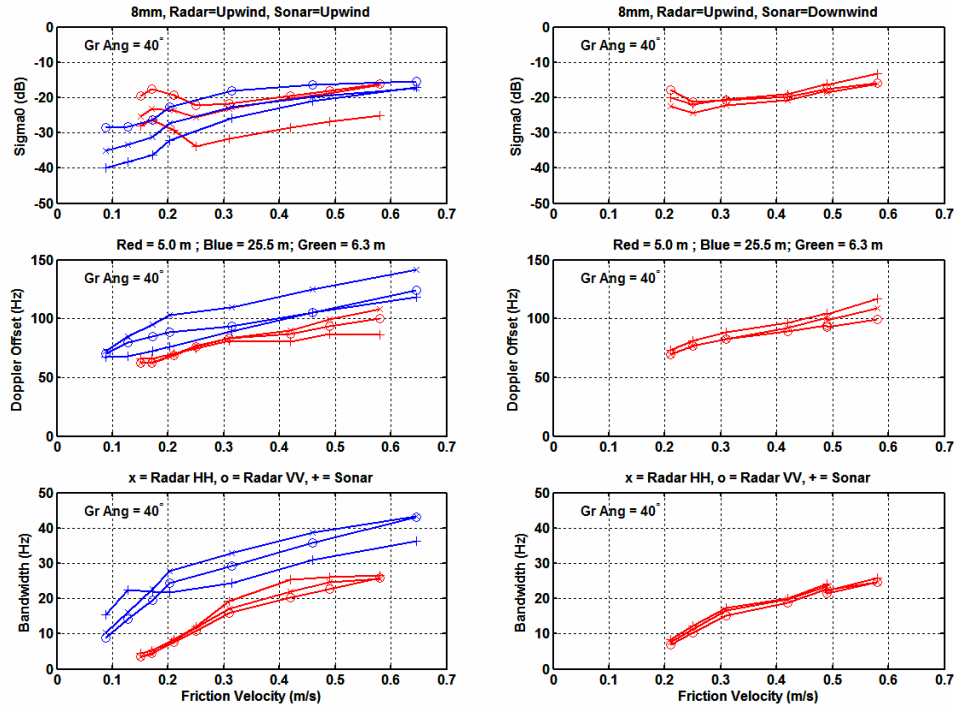
Figure 1. Backscatter characteristics at 8 mm. Left – Radar looking upwind, sonar looking upwind. Right – Radar looking upwind, sonar looking downwind.
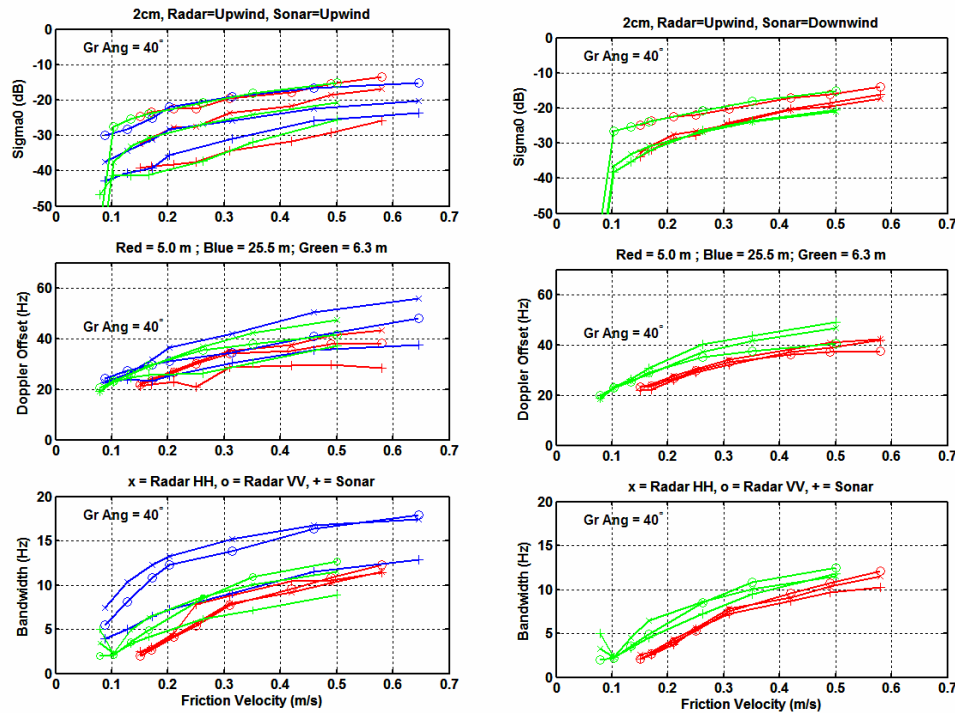
Figure 2. Backscatter characteristics at 2 cm. Left – Radar looking upwind, sonar looking upwind. Right – Radar looking upwind, sonar looking downwind.

Figure 2 shows the excellent agreement between measurements made in the two different tanks for 2 cm radiation: the cross sections are nearly identical. The figure clearly shows that backscatter of 2 cm radiation does not come primarily from parasitic capillaries. At all fetches, the cross sections from the different sensors are very similar and none show the excess at low wind speeds shown in the top left plot of Figure 1. Again, when the radar and sonar look in the same direction, acoustic backscatter is much lower than microwave while when they look in opposite directions, HH microwave and acoustic cross sections are very nearly the same. This is characteristic behavior of backscatter from bound, tilted waves. Once again, Doppler offsets and bandwidths generally increase with fetch, indicating backscatter from a scatterer traveling with the dominant wave. Note, however that when the sensors look in the same direction, a clearly discernable difference in offsets and bandwidths exists between the sensors even at very low wind speeds. This is in sharp contrast to the behavior of 8 mm backscatter at low wind speeds where offsets and bandwidths are the same for both sensors. We conclude that while 8 mm backscatter at low wind speeds and short fetches is due only to parasitic capillary waves, at higher wind speeds or longer fetches it is not. For 2 cm radiation scattering from other types of bound, tilted waves – breakers or microbreakers – appears to dominate under all conditions.

IMPACT/APPLICATION

The results of this work support previous measurements that have shown the importance of bound, tilted short waves for understanding rough surface scattering both in wind wave tanks and on the ocean (Plant, 1997; Plant et al, 1999b; Plant et al., 1999c). Although we have not demonstrated it in this report, a variety of data, including our Marseilles data, show that bound wave effects are more prominent at high incidence angles than at low ones. Thus their effects are important for developing scattering models at moderate to high incidence angles, especially at horizontal polarization. Abundant evidence exists that signatures of surface and subsurface vessels appear most prominently in microwave imagery taken at horizontal polarization and high incidence angles. Bound waves are undoubtedly one reason for this. Thus the work carried out in this project is directly applicable to non-acoustic ASW and other ocean imaging.

TRANSITIONS

The results of this project have not yet been transitioned for operational use.

RELATED PROJECTS

This project has many parallels with a project run by the Navy to investigate the microwave signatures produced by submarines. The basic understanding of microwave scattering, especially at high incidence angles, produced in this project furthers these attempts to detect submarines. Finally, knowledge of acoustic scattering obtained from this joint microwave/acoustic study benefits programs on acoustic scattering from the sea surface and near-surface bubbles sponsored by ONR Code 321OA.

REFERENCES

Fedorov, A.W., and W.K. Melville, Nonlinear gravity-capillary waves with forcing and dissipation, J. Fluid Mech., 354, 1-42, 1998.

Plant, W.J., A model for microwave Doppler sea return at high incidence angles: Bragg scattering from bound, tilted waves, J. Geophys. Res., 102(C9), 21131-21146, 1997.

Plant, W.J., P.H. Dahl, and W.C. Keller, Microwave and acoustic scattering from parasitic capillary waves, J. Geophys. Res., C11, 25,853-25865, 1999a.

Plant, W.J., W.C. Keller, V. Hesany, T. Hara, E. Bock, and M. Donelan, Bound waves and Bragg scattering in a wind wavetank, J. Geophys. Res., C2, 3243-3263, 1999b.

Plant, W.J., W.C. Keller, V. Hesany, K. Hayes, Peter Dahl, T. Hara, E. Bock, and M. Donelan, "Crumpling" wave effects in backscatter from the air-sea interface, Proceedings of the Sydney Air/Sea Interaction Symposium, Edited by Michael Banner, 1999c.